A New Electromagnetic Exposure Metric: High Frequency Voltage Transients Associated With Increased Cancer Incidence in Teachers in a California School

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Background *In 2003 the teachers at La Quinta, California middle school complained that they had more cancers than would be expected. A consultant for the school district denied that there was a problem.*

Objectives *To investigate the cancer incidence in the teachers, and its cause.*

Method *We conducted a retrospective study of cancer incidence in the teachers' cohort in relationship to the school's electrical environment.*

Results *Sixteen school teachers in a cohort of 137 teachers hired in 1988 through 2005 were diagnosed with 18 cancers. The observed to expected (O/E) risk ratio for all cancers was 2.78 ($P = 0.000098$), while the O/E risk ratio for malignant melanoma was 9.8 ($P = 0.0008$). Thyroid cancer had a risk ratio of 13.3 ($P = 0.0098$), and uterine cancer had a risk ratio of 9.2 ($P = 0.019$). Sixty Hertz magnetic fields showed no association with cancer incidence. A new exposure metric, high frequency voltage transients, did show a positive correlation to cancer incidence. A cohort cancer incidence analysis of the teacher population showed a positive trend ($P = 7.1 \times 10^{-10}$) of increasing cancer risk with increasing cumulative exposure to high frequency voltage transients on the classroom's electrical wiring measured with a Graham/Stetzer (G/S) meter. The attributable risk of cancer associated with this exposure was 64%. A single year of employment at this school increased a teacher's cancer risk by 21%.*

Conclusion *The cancer incidence in the teachers at this school is unusually high and is strongly associated with high frequency voltage transients, which may be a universal carcinogen, similar to ionizing radiation.* Am. J. Ind. Med. 2008. © *2008 Wiley-Liss, Inc.*

KEY WORDS: high frequency voltage transients; electricity; dirty power; cancer; school teachers; carcinogen

BACKGROUND

Since the 1979 Wertheimer–Leeper study [Wertheimer and Leeper, 1979] there has been concern that exposure to power frequency (50/60 Hz) EMFs, especially magnetic fields, may contribute to adverse health effects including cancer. Until now, the most commonly used exposure metric has been the time-weighted average of the power-frequency magnetic field. However, the low risk ratios in most studies suggest that magnetic fields might be a surrogate for a more important metric. In this paper we present evidence that a

Abbreviations: EMF, electromagnetic fields; O, observed cases; E, expected cases; O/E, risk ratio; p, probability; Hz, Hertz or cycles per second; OSHA, Occupational Safety and Health Administration; OCMAP, occupational mortality analysis program; AM, amplitude modulation; GS units, Graham/Stetzer units; G/S meter, Graham/Stetzer meter; MS II, Microsurge II meter; mG, milligauss; EKG, electrocardiogram; LQMS, La Quinta Middle School.

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new exposure metric, high frequency voltage transients existing on electrical power wiring, is an important predictor of cancer incidence in an exposed population.

The new metric, GS units, used in this investigation is measured with a Graham/Stetzer meter (G/S meter) also known as a Microsurge II meter (MS II meter), which is plugged into electric outlets [Graham, 2005]. This meter displays the average rate of change of these high frequency voltage transients that exist everywhere on electric power wiring. High frequency voltage transients found on electrical wiring both inside and outside of buildings are caused by an interruption of electrical current flow. The electrical utility industry has referred to these transients as "dirty power."

There are many sources of "dirty power" in today's electrical equipment. Examples of electrical equipment designed to operate with interrupted current flow are light dimmer switches that interrupt the current twice per cycle (120 times/s), power saving compact fluorescent lights that interrupt the current at least 20,000 times/s, halogen lamps, electronic transformers and most electronic equipment manufactured since the mid-1980s that use switching power supplies. Dirty power generated by electrical equipment in a building is distributed throughout the building on the electric wiring. Dirty power generated outside the building enters the building on electric wiring and through ground rods and conductive plumbing, while within buildings, it is usually the result of interrupted current generated by electrical appliances and equipment.

Each interruption of current flow results in a voltage spike described by the equation $V = L \times di/dt$, where V is the voltage, L is the inductance of the electrical wiring circuit and di/dt is the rate of change of the interrupted current. The voltage spike decays in an oscillatory manner. The oscillation frequency is the resonant frequency of the electrical circuit. The G/S meter measures the average magnitude of the rate of change of voltage as a function of time (dV/dT). This preferentially measures the higher frequency transients. The measurements of dV/dT read by the meter are defined as GS (Graham/Stetzer) units.

The bandwidth of the G/S meter is in the frequency range of these decaying oscillations. Figure 1 shows a two-channel oscilloscope display. One channel displays the 60 Hz voltage on an electrical outlet while the other channel with a 10 kHz hi-pass filter between the oscilloscope and the electrical outlet, displays the high frequency voltage transients on the same electrical outlet [Havas and Stetzer, 2004, reproduced with permission].

Although no other published studies have measured high frequency voltage transients and risk of cancer, one study of electric utility workers exposed to transients from pulsed

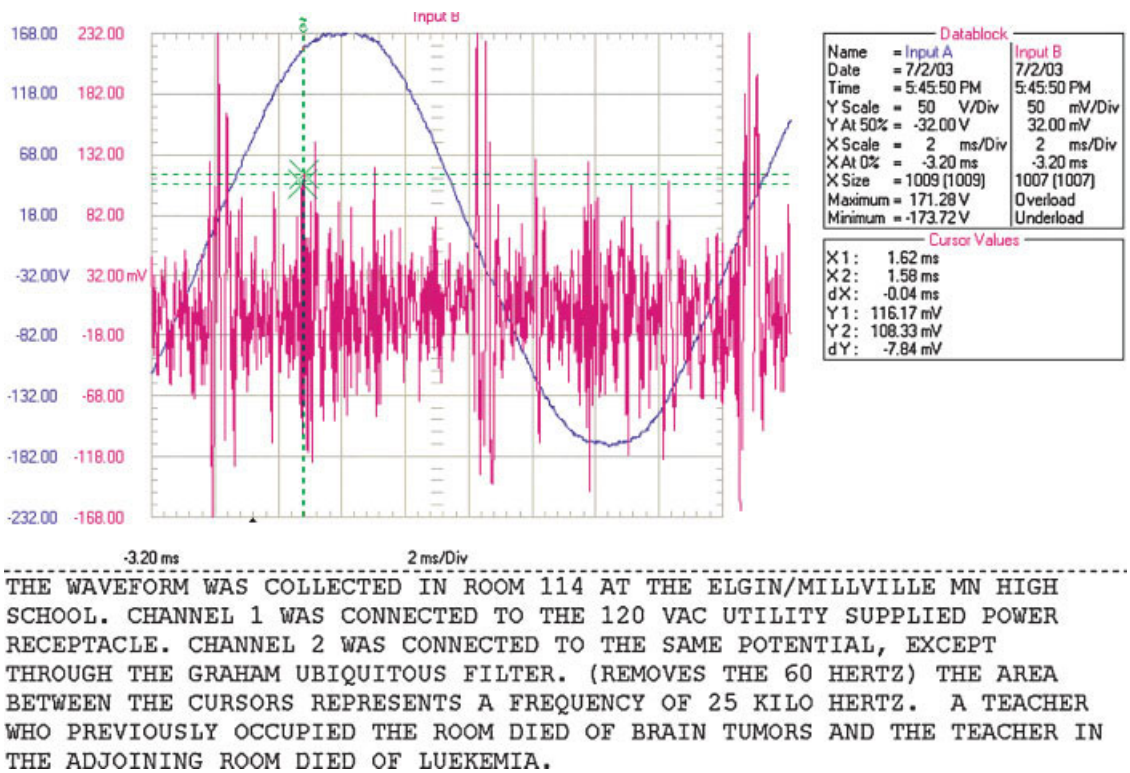

Input B
168.00 232.00
118.00 182.00
68.00 132.00
18.00 82.00
-32.00 V 32.00 mV
-82.00 -18.00
-132.00 -68.00
-182.00 -118.00
-232.00 -168.00
-3.20 ms
2 ms/Div
Datablock
Name = Input A Input B
Date = 7/2/03 7/2/03
Time = 5:45:50 PM 5:45:50 PM
Y Scale = 50 V/Div 50 mV/Div
Y At 50% = -32.00 V 32.00 mV
X Scale = 2 ms/Div 2 ms/Div
X At 0% = -3.20 ms -3.20 ms
X Size = 1009 (1009) 1007 (1007)
Maximum = 171.28 V Overload
Minimum = -173.72 V Underload
Cursor Values
X1: 1.62 ms
X2: 1.58 ms
dX: -0.04 ms
Y1: 116.17 mV
Y2: 108.33 mV
dY: -7.84 mV
THE WAVEFORM WAS COLLECTED IN ROOM 114 AT THE ELGIN/MILLVILLE MN HIGH SCHOOL. CHANNEL 1 WAS CONNECTED TO THE 120 VAC UTILITY SUPPLIED POWER RECEPTACLE. CHANNEL 2 WAS CONNECTED TO THE SAME POTENTIAL, EXCEPT THROUGH THE GRAHAM UBIQUITOUS FILTER. (REMOVES THE 60 HERTZ) THE AREA BETWEEN THE CURSORS REPRESENTS A FREQUENCY OF 25 KILO HERTZ. A TEACHER WHO PREVIOUSLY OCCUPIED THE ROOM DIED OF BRAIN TUMORS AND THE TEACHER IN THE ADJOINING ROOM DIED OF LUEKEMIA.

FIGURE 1. Oscilloscope display of dirty power: 60 Hz electrical power (channel 1) with concurrent high frequency voltage transients (channel 2). A 10 kHz hi-pass filter was used on channel 2 in order to filter out the 60 Hz voltage and its harmonics. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

electromagnetic fields found an increased incidence of lung cancer among exposed workers [Armstrong et al., 1994].

INTRODUCTION

In February 2004, a Palm Springs, California newspaper, The Desert Sun, printed an article titled, ''Specialist discounts cancer cluster at school,'' in which a local tumor registry epidemiologist claimed that there was no cancer cluster or increased cancer incidence at the school [Perrault, 2004]. An Internet search revealed that the teacher population at La Quinta Middle School (LQMS) was too small to generate the 11 teachers with cancer who were reported in the article. The school was opened in 1988 with 20 teachers hired that year. For the first 2 years, the school operated in three temporary buildings, one of which remains. In 1990, a newly constructed school opened. In 2003, the teachers complained to school district management that they believed that they had too many cancers. Repeated requests to the school administration for physical access to the school and for teachers' information were denied. We contacted the teachers, and with their help, the cancers in the group were characterized. One teacher suggested using yearbooks to develop population-at-risk counts for calculating expected cancers. We were anxious to assess the electrical environment at the school, since elevated power frequency magnetic field exposure with a positive correlation between duration of exposure and cancer incidence had been reported in first floor office workers who worked in strong magnetic fields above three basement-mounted 12,000 V transformers [Milham, 1996]. We also wanted to use a new electrical measurement tool, the Graham/Stetzer meter, which measures high frequency voltage transients.

The Graham/Stetzer Microsurge II meter measures the average rate of change of the transients in Graham/Stetzer units (GS units). Anecdotal reports had linked dirty power exposure with a number of illnesses [Havas and Stetzer, 2004]. We decided to investigate whether power frequency magnetic field exposure or dirty power exposure could explain the cancer increase in the school teachers.

METHODS

After the school administration (Desert Sands Unified School District) had refused a number of requests to assist in helping us evaluate the cancers reported by the teachers, we were invited by a teacher to visit the school after hours to make magnetic field and dirty power measurements. During that visit, we noted that, with the exception of one classroom near the electrical service room, the classroom magnetic field levels were uniformly low, but the dirty power levels were very high, giving many overload readings. When we reported this to Dr. Doris Wilson, then the superintendent of schools (retired December, 2007), one of us (SM) was threatened with prosecution for ''unlawful.. trespass,'' and the teacher who had invited us into the school received a letter of reprimand. The teachers then filed a California OSHA complaint which ultimately lead to a thorough measurement of magnetic fields and dirty power levels at the school by the California Department of Health Services which provided the exposure data for this study. They also provided comparison dirty power data from residences and an office building, and expedited tumor registry confirmation of cancer cases.

Classrooms were measured at different times using 3 meters: an FW Bell model 4080 tri-axial Gaussmeter, a Dexsil 310 Gaussmeter, and a Graham-Stetzer (G/S) meter. The Bell meter measures magnetic fields between 25 and 1,000 Hz. The Dexsil meter measures magnetic fields between 30 and 300 Hz. The G/S meter measures the average rate of change of the high frequency voltage transients between 4 and 150 KHz.

All measurements of high frequency voltage transients were made with the G/S meter. This meter was plugged into outlets, and a liquid crystal display was read. All measurements reported were in GS units. The average value was reported where more than one measurement was made in a classroom.

We measured seven classrooms in February 2005 using the Bell meter and the G/S meter. Later in 2005, the teachers measured 37 rooms using the same meters. On June 8, 2006, electrical consultants for the school district and the California Department of Health Services (Dr. Raymond Neutra) repeated the survey using the G/S meter and a Dexsil 320 Gaussmeter, measuring 51 rooms. We used results of this June 8, 2006 sampling in our exposure calculations, since all classrooms were sampled, multiple outlets per room were sampled, and an experienced team did the sampling. Additionally, GS readings were taken at Griffin Elementary school near Olympia, Washington, and Dr. Raymond Neutra provided GS readings for his Richmond California office building and 125 private California residences measured in another Northern California study.

All the cancer case information was developed by personal, telephone, and E-mail contact with the teachers or their families without any assistance from the school district. The local tumor registry verified all the cancer cases with the exception of one case diagnosed out of state and the two cases reported in 2007. The out-of state case was verified by pathologic information provided by the treating hospital. The teachers gathered population-at-risk information (age at hire, year of hire, vital status, date of diagnosis, date of death, and termination year) from yearbooks and from personal contact. The teachers also provided a history of classroom assignments for all teachers from annual classroom assignment rosters (academic years 1990–1991 to 2006–2007) generated by the school administration. The school administration provided a listing of school employees, including

the teachers, to the regional tumor registry after the teachers involved the state health agency by submitting an OSHA complaint. The information we obtained anecdotally from the teachers, yearbooks, and classroom assignment rosters was nearly identical to that given to the tumor registry. None of the cancer cases were ascertained initially through the cancer registry search.

Published cancer incidence rates by age, sex, and race for all cancers, as well as for malignant melanoma, thyroid, uterine, breast, colon, ovarian cancers, and non-Hodgkin's lymphoma (NHL) were obtained from a California Cancer Registry publication [Kwong et al., 2001]. We estimated the expected cancer rate for each teacher by applying year, age, sex, and race-specific cancer incidence rates from hire date until June 2007, or until death. We then summed each teacher's expected cancer rate for the total cohort.

Using the California cancer incidence data, the school teacher data, and the GS exposure data, we calculated cancer incidence and risks. A replicate data set was sent to Dr. Gary Marsh and to Mike Cunningham at the University of Pittsburgh School of Public Health for independent analysis using OCMAP software. We calculated cancer risk ratios by duration of employment and by cumulative GS unit-years of exposure. We calculated an attributable risk percent using the frequencies of total observed and expected cancers, and performed trend tests [Breslow and Day, 1987] for cancer risk versus duration of employment and cumulative GS unit-years of exposure. Poisson *P* values were calculated using the Stat Trek website (Stat Trek, 2007). We also performed a linear regression of cancer risk by duration of employment in years and by time-weighted exposure in GS unit-years.

Since neither author had a current institutional affiliation, institutional review board approval was not possible. The teachers requested the study, and their participation in the study was both voluntary and complete. All the active teachers at the school signed the Cal OSHA request. The authors fully explained the nature of the study to study participants and offered no remuneration to the teachers for participation in the study. The authors maintained strict confidentiality of all medical and personal information provided to us by the teachers, and removed personal identifiers from the data set which was analyzed by the University of Pittsburgh. Possession of personal medical information was limited to the two authors. No patient-specific information was obtained from the tumor registry. With the individual's permission we provided the registry with case information for a teacher with malignant melanoma diagnosed out of state. The exposure information was provided by the California Department of Health Services. The basic findings of the study were presented to the Desert Sands Unified School District School Board and at a public meeting arranged by the teachers.

RESULTS

Electrical Measurements

In our seven-room survey of the school in 2005, magnetic field readings were as high as 177 mG in a classroom adjacent to the electrical service room. A number of outlets had overload readings with the G/S meter. Magnetic fields were not elevated ($>$3.0 mG) in the interior space of any of the classrooms except in the classroom adjacent to the electrical service room, and near classroom electrical appliances such as overhead transparency projectors. There was no association between the risk of cancer and 60 Hz magnetic field exposures in this cohort, since the classroom magnetic field exposures were the same for teachers with and without cancer (results not shown).

This school had very high GS readings and an association between high frequency voltage transient exposure in the teachers and risk of cancer. The G/S meter gives readings in the range from 0 to 1,999 GS units. The case school had 13 of 51 measured rooms with at least one electrical outlet measuring ''overload'' ($\geq$2,000 GS units). These readings were high compared to another school near Olympia Washington, a Richmond California office building, and private residences in Northern California (Table I). Altogether, 631 rooms were surveyed for this study. Only 17 (2.69%) of the 631 rooms had an ''overload'' (maximum, $\geq$2,000 GS units) reading. Applying this percentage to the 51 rooms surveyed at the case school, we would expect 1.4 rooms at the school to have overload GS readings ($0.0269 \times 51 = 1.37$). However, thirteen rooms (25%) measured at the case school had ''overload'' measurements above the highest value (1,999 GS units) that the G/S meter can

TABLE I. Graham/Stetzer Meter Readings: Median Values in Schools, Homes and an Office Building

Place	Homes	Office bldg	Olympia WA School	LQMS	Total
No. of rooms surveyed	500	39	41	51	531
Median GS units	159	210	160	750	<270[a]
Rooms with overload GS units ($\geq$2,000)	4	0	0	13*	17

[a]Excludes homes as specific room data was not available.
*$P = 3.14 \times 10^{-9}$.

TABLE II. Risk of Cancer by Type Among Teachers at La Quinta Middle School

Cancer	Observed	Expected	Risk ratio (O/E)	*P*-value
All cancers	18	6.51	2.78*	0.000098
Malignant melanoma	4	0.41	9.76*	0.0008
Thyroid cancer	2	0.15	13.3*	0.011
Uterus cancer	2	0.22	9.19*	0.019
Female breast cancer	2	1.5	1.34	0.24
All cancers less melanoma	14	6.10	2.30*	0.0025

*$P \leq 0.05$.

measure. This is a highly statistically significant excess over expectation (Poisson $P = 3.14 \times 10^{-9}$).

We noticed AM radio interference in the vicinity of the school. A teacher also reported similar radio interference in his classroom and in the field near his ground floor classroom. In May 2007, he reported that 11 of 15 outlets in his classroom overloaded the G/S meter. An AM radio tuned off station is a sensitive detector of dirty power, giving a loud buzzing noise in the presence of dirty power sources even though the AM band is beyond the bandwidth of the G/S meter.

Cancer Incidence

Three more teachers were diagnosed with cancer in 2005 after the first 11 cancer diagnoses were reported, and another former teacher (diagnosed out-of-state in 2000) was reported by a family member employed in the school system. One cancer was diagnosed in 2006 and two more in 2007. In the years 1988–2005, 137 teachers were employed at the school. The 18 cancers in the 16 teachers were: 4 malignant melanomas, 2 female breast cancers, 2 cancers of the thyroid, 2 uterine cancers and one each of Burkitt's lymphoma (a type of non-Hodgkins lymphoma), polycythemia vera, multiple myeloma, leiomyosarcoma and cancer of the colon, pancreas, ovary and larynx. Two teachers had two primary cancers each: malignant melanoma and multiple myeloma, and colon and pancreatic cancer. Four teachers had died of cancer through August 2007. There have been no non-cancer deaths to date.

The teachers' cohort accumulated 1,576 teacher-years of risk between September 1988 and June 2007 based on a 12-month academic year. Average age at hire was 36 years. In 2007, the average age of the cohort was 47.5 years.

When we applied total cancer and specific cancer incidence rates by year, age, sex, race, and adjusted for cohort ageing, we found an estimate of 6.5 expected cancers, 0.41 melanomas, 0.15 thyroid cancers, 0.22 uterine cancers, and 1.5 female breast cancers (Table II). For all cancers, the risk ratio (Observed/Expected = 18/6.5) was 2.78 ($P = 0.000098$, Poisson test); for melanoma, (O/E = 4/0.41) was 9.8 ($P = 0.0008$, Poisson test); for thyroid cancer (O/E = 2/0.15) was 13.3 ($P = 0.0011$, Poisson test); for uterine cancer (O/E = 2/0.22), was 9.19 ($P = 0.019$, Poisson test).

Table III shows the cancer risk among the teachers by duration of employment. Half the teachers worked at the school for less than 3 years (average 1.52 years). The cancer risk increases with duration of employment, as is expected when there is exposure to an occupational carcinogen. The cancer risk ratio rose from 1.7 for less than 3 years, to 2.9 for 3–14 years, to 4.2 for 15+ years of employment. There was a positive trend of increasing cancer incidence with increasing duration of employment ($P = 4.6 \times 10^{-10}$). A single year of employment at this school increases a teacher's risk of cancer by 21%.

Using the June 8, 2006 survey data (Table IV), the cancer risk of a teacher having ever worked in a room with at least one outlet with an overload GS reading ($\geq$2000 GS units) and employed for 10 years or more, was 7.1 ($P = 0.00007$, Poisson test). In this group, there were six teachers diagnosed

TABLE III. Cancer Risk by Duration of Employment

Time at school	Average time	Teachers	% of teachers	Cancer observed	Cancer expected	Risk ratio (O/E)	Poisson p
<3 years	1.52 years	68	49.6	4	2.34	1.72	0.12
3–14 years	7.48 years	56	40.9	9	3.14	2.87*	0.0037
15+ years	16.77 years	12	8.8	5	1.02	4.89*	0.0034
Total		137	100	18	6.51	2.78*	0.000098

Positive trend test (Chi square with one degree of freedom = 38.8, $P = 4.61 \times 10^{-10}$).
*$P \leq 0.05$.

TABLE IV. Cancer in Teachers Who Ever Taught in Classrooms With at Least One Overload GS Reading (≥2000 GS Units) by Duration of Employment

Ever in a room >2,000 GS units	Employed 10 + years	Total teachers	Cancers observed	Cancers expected	Risk ratio (O/E)	Poisson p
Yes	Yes	10	7[a]	0.988	7.1*	0.00007
Yes	No	30	3[a]	0.939	3.2	0.054
Total		40	10	1.93	5.1*	0.00003
No	Yes	19	2	1.28	1.6	0.23
No	No	78	6	3.25	1.8	0.063
Total		97	8	4.56	1.8*	0.047
Grand total		137	18	6.49	2.8*	0.000098

[a]One teacher had two primary cancers.
*$P < 0.05$.

with a total of seven cancers, and four teachers without a cancer diagnosis, who were employed for 10 or more years and who ever worked in one of these rooms. Five teachers had one primary cancer and one teacher had two primary cancers. These teachers made up 7.3% of the teachers' population (10/137) but had 7 cancers or 39% (7/18) of the total cancers. The 10 teachers who worked in an overload classroom for 10 years or more had 7 cancers when 0.99 would have been expected ($P = 6.8 \times 10^{-5}$ Poisson test). The risk ratio for the 8 teachers with cancer and 32 teachers without cancer, who ever worked in a room with an overload GS reading, regardless of the time at the school, was 5.1 ($P = 0.00003$, Poisson test). The risk ratio for 8 teachers with cancer and 89 teachers without cancer who never worked in a room with an overload G-S reading was 1.8 ($P = 0.047$, Poisson test). Teachers who never worked in an overload classroom also had a statistically significantly increased risk of cancer.

A positive dose-response was seen between the risk of cancer and the cumulative GS exposure (Table V). Three categories of cumulative GS unit-years of exposure were selected: <5,000, 5,000 to 10,000, and more than 10,000 cumulative GS unit-years. We found elevated risk ratios of 2.0, 5.0, and 4.2, respectively, all statistically significant, for each category. There was a positive trend of increasing cancer incidence with increasing cumulative GS unit-years of exposure ($P = 7.1 \times 10^{-10}$). An exposure of 1,000 GS unit-years increased a teacher's cancer risk by 13%. Working in a room with a GS overload (≥2,000 GS units) for 1 year increased cancer risk by 26%.

An attributable risk percentage was calculated: (observed cancers-expected cancers)/observed cancers = $(18-6.51)/18 = 63.8\%$.

The fact that these cancer incidence findings were generated by a single day of G/S meter readings made on June 8, 2006 suggests that the readings were fairly constant over time since the school was built in 1990. For example, if the 13 classrooms which overloaded the meter on June 8, 2006 were not the same since the start of the study and constant throughout, the cancer risk of teachers who ever worked in the overload rooms would have been the same as the teachers who never worked in an overload room.

Although teachers with melanoma and cancers of the thyroid, and uterus, had very high, statistically significant risk ratios, there was nothing exceptional about their age at hire, duration of employment, or cumulative GS exposure. However, thyroid cancer and melanoma had relatively short latency times compared to the average latency time for all 18 cancers. The average latency time between start of

TABLE V. Observed and Expected Cancers by Cumulative GS Exposure (GS Unit-Years)

Exposure group	<5,000 GS unit-years	5,000 to 10,000	>10,000 GS unit-years	Total
Average GS unit-years	914	7,007	15,483	
Cancers obs.	9	4	5	18
Cancers exp.	4.507	0.799	1.20	6.49
Risk ratio (O/E)	2.01*	5.00*	4.17*	2.78*
Poisson p	0.0229	0.0076	0.0062	0.000098

Positive trend test (Chi square with one degree of freedom = 38.0, $P = 7.1 \times 10^{-10}$).
*$P < 0.05$.

employment at the school and diagnosis for all cancers was 9.7 years. The average latency time for thyroid cancer was 3.0 years and for melanoma it was 7.3 years (with three of the four cases diagnosed at 2, 5, and 5 years).

An independent analysis of this data set by the University of Pittsburgh School of Public Health using OCMAP software supported our findings.

DISCUSSION

Because of access denial, we have no information about the source, or characterization of the high frequency voltage transients. We can assume, because the school uses metal conduit to contain the electrical wiring, that any resultant radiated electric fields from these high frequency voltage transients would radiate mainly from the power cords and from electrical equipment using the power cords within a classroom.

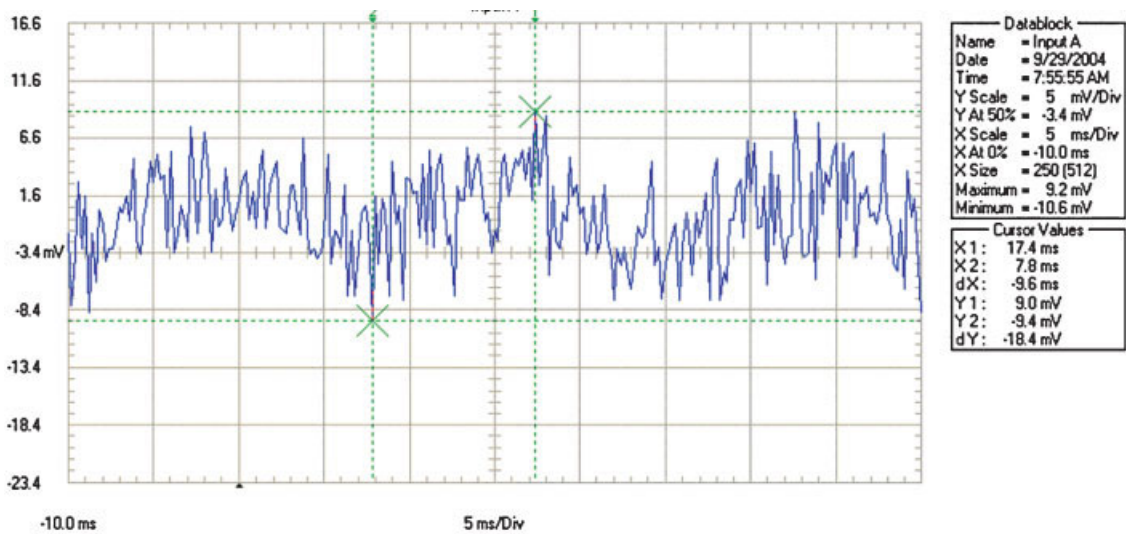
The school's GS readings of high frequency voltage transients are much higher than in other tested places (Table I). Also, teachers in the case school who were employed for over 10 years and who had ever worked in a room with an overload GS reading had a much higher rate of cancer. They made up 7.3% of the cohort but experienced 39% of all cancers.

The relatively short latency time of melanoma and thyroid cancers suggests that these cancers may be more sensitive to the effects of high frequency voltage transients than the other cancers seen in this population.

In occupational cohort studies, it is very unusual to have a number of different cancers with an increased risk. An exception to this is that cohorts exposed to ionizing radiation show an increased incidence of a number of different cancers. The three cancers in this cohort with significantly elevated incidence, malignant melanoma, thyroid cancer and uterine cancer, also have significantly elevated incidence in the large California school employees cohort [Reynolds et al., 1999].

These cancer risk estimates are probably low because 23 of the 137 members of the cohort remain untraced. Since exposure was calculated based on 7 days a week for a year, this will overstate the actual teachers' exposure of 5 days a week for 9 months a year.

We could not study field exposures in the classrooms since we were denied access to the school. We postulate that the dirty power in the classroom wiring exerted its effect by capacitive coupling which induced electrical currents in the



The waveform was recorded between 2 EKG patches placed on the ankles of XXXXXX XXXXXXXXX standing in front of his kitchen sink at his home near Bright Ontario. It shows a distorted 60 cycle sine wave containing high frequencies applied to each foot, allowing high frequency current to freely oscillate up one leg and down the other. XXXXXX has been diagnosed with prostrate cancer since moving to the house in less than a year. He was standing with feet shoulder width apart, wearing shoes, at the time of the readings. The amplitude increased as the feet were placed farther apart.

FIGURE 2. Oscilliscope display of 60 Hz current distorted with high frequencies taken between EKG patches applied to the ankles of a man standing with shoes on at a kitchen sink. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

teachers' bodies. The energy that is capacitively coupled to the teachers' bodies is proportional to the frequency. It is this characteristic that highlights the usefulness of the G/S meter. High frequency dirty power travels along the electrical distribution system in and between buildings and through the ground. Humans and conducting objects in contact with the ground become part of the circuit. Figure 2 [Havas and Stetzer, 2004, reproduced with permission] shows an oscilloscope tracing taken between EKG patches on the ankles of a man wearing shoes, standing at a kitchen sink. The 60 Hz sine wave is distorted by high frequencies, which allows high frequency currents to oscillate up one leg and down the other between the EKG patches.

Although not demonstrated in this data set, dirty power levels are usually higher in environments with high levels of 60 Hz magnetic fields. Many of the electronic devices which generate magnetic fields also inject dirty power into the utility wiring. Magnetic fields may, therefore, be a surrogate for dirty power exposures. In future studies of the EMF-cancer association, dirty power levels should be studied along with magnetic fields.

The question of cancer incidence in students who attended La Quinta Middle School for 3 years has not been addressed.

CONCLUSION

The cancer incidence in the teachers at this school is unusually high and is strongly associated with exposure to high frequency voltage transients. In the 28 years since electromagnetic fields (EMFs) were first associated with cancer, a number of exposure metrics have been suggested. If our findings are substantiated, high frequency voltage transients are a new and important exposure metric and a possible universal human carcinogen similar to ionizing radiation.

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REFERENCES

Armstrong B, Theriault G, Guenel P, Deadman J, Goldberg M, Heroux P. 1994. Association between exposure to pulsed electromagnetic fields and cancer in electric utility workers in Quebec, Canada, and France. Am J Epidemiol 140(9):805–820.

Breslow NE, Day NE. 1987. Statistical Methods in Cancer Research, Vol. II—The Design and Analysis of Cohort Studies. IARC Scientific Publication No. 82, International Agency for Research on Cancer, Lyon France, 1987.96 (equation 3.12).

Graham MH. 2005. Circuit for Measurement of Electrical Pollution on Power Line. United States Patent 6,914,435 B2.

Havas M, Stetzer D. 2004. Dirty electricity and electrical hypersensitivity: Five case studies. World Health Organization Workshop on Electrical Hypersensitivity. 25–26 October, Prague, Czech Republic, available online at: http://www.stetzerelectric.com/filters/research/havas_stetzer_who04.pdf.

Kwong SL, Perkins CI, Morris CR, Cohen R, Allen M, Wright WE. 2001. Cancer in California 1988–1999. Sacramento CA: California Department of Health Services, Cancer Surveillance Section.

Milham S. 1996. Increased incidence of cancer in a cohort of office workers exposed to strong magnetic fields. Am J Ind Med 30(6):702–704.

Perrault M. 2004. Specialist Discounts Cancer Cluster at School. The Desert Sun (Palm Springs, CA), 22 February, A1.

Reynolds P, Elkin EP, Layefsky ME, Lee JM. 1999. Cancer in California school employees. Am J Ind Med 36:271–278.

Stat Trek http://stattrek.com/tables/poisson.aspx (accessed August 2007).

Wertheimer N, Leeper E. 1979. Electrical wiring configurations and childhood cancer. Am J Epidemiol 109(3):273–284.